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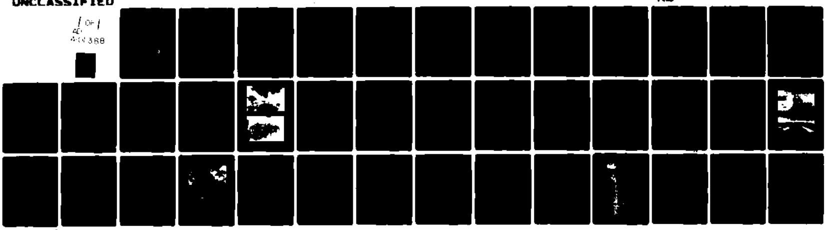

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STREAM CHANNEL STABILITY

APPENDIX C

INVESTIGATIONS OF VEGETATION FOR STABILIZING ERODING STREAM BANKS

Project Objective 2

by

A. J. Bowie

USDA Sedimentation Laboratory
Oxford, Mississippi

April 1981

Prepared for
US Army Corps of Engineers, Vicksburg District
Vicksburg, Mississippi

Under
Section 32 Program, Work Unit 7

STREAM CHANNEL STABILITY

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1/ Research Hydraulic Engineer, Sediment Yield Research Unit, USDA Sedimentation Laboratory, Oxford, MS.

Preface

Effective streambank protection measures are costly to install, thus a determined effort should be made to use vegetation because it is the most readily available material and is relatively inexpensive to obtain. Vegetation greatly reduces the hydraulic forces on the bank and provides other esthetic and environmental advantages over other methods of stabilization. This report describes a series of streambank vegetative studies located on the channels of Johnson, Goodwin and Peters Creek in Panola County near Batesville, Mississippi. On Johnson Creek, there are four sites; two of them use vegetation in conjunction with bank shaping and structural materials, the other two sites use vegetation in conjunction with structural devices without bank shaping. The site on Goodwin Creek uses vegetation in conjunction with bank shaping, with and without structural materials. The Peters Creek sites use woody vegetation in conjunction with structural devices without bank shaping. Criteria used in the design of the combined vegetative and structural projects are presented along with a detailed description of the project sites. Since these type studies require several years to evaluate, only preliminary results are presented and many of them are based on previous experience.

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CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI) AND METRIC (SI) TO U.S. CUSTOMARY UNITS OF MEASUREMENT1/

Units of measurement used in this report can be converted as follows:

To convert	To	Multiply by
mils (mil)	micron (µm)	25.4
inches (in)	millimeters (mm)	25.4
feet (ft)	meters (m)	0.305
yards (yd)	meters (m)	0.914
miles (miles)	kilometers (km)	1.61
inches per hour (in/hr)	millimeters per hour (mm/hr)	25.4
feet per second (ft/sec)	meters per second (m/sec)	0.305
square inches (sq in)	square millimeters (mm^2)	645.
square feet (sq ft)	square meters (m^2)	0.093
square yards (sq yd)	square meters (m^2)	0.836
square miles (sq miles)	square kilometers (km^2)	2.59
acres (acre)	hectares (ha)	0.405
acres (acre)	square meters (m^2)	4,050.
cubic inches (cu in)	cubic millimeters (mm^3)	16,400.
cubic feet (cu ft)	cubic meters (m^3)	0.0283
cubic yards (cu yd)	cubic meters (m^3)	0.765
cubic feet per second (cfs)	cubic meters per second (cms)	0.0283
pounds (lb) mass	grams (g)	454.
pounds (lb) mass	kilograms (kg)	0.453
tons (ton) mass	kilograms (kg)	907.
pounds force (lbf)	newtons (N)	4.45
kilogram force (kgf)	newtons (N)	9.81
foot pound force (ft lbf)	joules (J)	1.36
pounds force per square foot (psf)	pascals (Pa)	47.9
pounds force per square inch (psi)	kilopascals (kPa)	6.89
pounds mass per square foot (lb/sq ft)	kilograms per square meter (kg/m^2)	4.88
U.S. gallons (gal)	liters (L)	3.79
quart (qt)	liters (L)	0.946
acre-feet (acre-ft)	cubic meters (m^3)	1,230.
degrees (angular)	radians (rad)	0.0175
degrees Fahrenheit (F)	degrees Celsius (C)2/	0.555

2/ To obtain Celsius (C) readings from Fahrenheit (F) readings, use the following formula: C = 0.555 (F-32).

Metric (SI) to U.S. Customary

To convert	To	Multiply by
micron (μm)	mils (mil)	0.0394
millimeters (mm)	inches (in)	0.0394
meters (m)	feet (ft)	3.28
meters (m)	yards (yd)	1.09
kilometers (km)	miles (miles)	0.621
millimeters per hour (mm/hr)	inches per hour (in/hr)	0.0394
meters per second (m/sec)	feet per second (ft/sec)	3.28
square millimeters (mm^2)	square inches (sq in)	0.00155
square meters (m^2)	square feet (sq ft)	10.8
square meters (m^2)	square yards (sq yd)	1.20
square kilometers (km^2)	square miles (sq miles)	0.386
hectares (ha)	acres (acre)	2.47
square meters (m^2)	acres (acre)	0.000247
cubic millimeters (mm^3)	cubic inches (cu in)	0.0000610
cubic meters (m^3)	cubic feet (cu ft)	35.3
cubic meters (m^3)	cubic yards (cu yd)	1.31
cubic meters per second (cms)	cubic feet per second (cfs)	35.3
grams (g)	pounds (lb) mass	0.00220
kilograms (kg)	pounds (lb) mass	2.20
kilograms (kg)	tons (ton) mass	0.00110
newtons (N)	pounds force (lbf)	0.225
newtons (N)	kilogram force (kgf)	0.102
joules (J)	foot pound force (ft lbf)	0.738
pascals (Pa)	pounds force per square foot (psf)	0.0209
kilopascals (kPa)	pounds force per square inch (psi)	0.145
kilograms per square meter (kg/m^2)	pounds mass per square foot lb/sq ft)	0.205
liters (L)	U.S. gallons (gal)	0.264
liters (L)	quart (qt)	1.06
cubic meters (m^3)	acre-feet (acre-ft)	0.000811
radians (rad)	degrees (angular)	57.3
degrees Celsius (C)	degrees Fahrenheit (F)3/	1.8

1/ All conversion factors to three significant digits.

3/ To obtain Fahrenheit (F) readings from Celsius (C) readings, use the following formula: F = 1.8C + 32.

INVESTIGATIONS OF VEGETATION FOR STABILIZING ERODING STREAMBANKS

1 INTRODUCTION

Erosion of channel banks may lead to catastrophic damage to land and adjoining physical property. This erosion process usually occurs as direct erosion of the embankment by flood water or the washing away of detached material after massive bank failure of sloughing or sliding. The sloughing or sliding process is usually triggered by reduction of the upper bank internal strength by saturation, foundation deterioration caused by seepage, and undermining of the toe of the bank.

Bank erosion is a common occurrence along many miles of streams throughout the entire country and is considered a national problem. In many sections of the country, this problem has reached acute stages. Barnes (1968) estimated that 300,000 miles of eroding streambanks in the United States produced approximately 500 million tons of sediment each year. This channel erosion is very costly to man. The cost of removing sediment from choked stream channels and reservoirs is estimated to cost in excess of $250 million a year. In addition, the loss of prime agricultural land and physical property adjacent to eroding streambanks is valued at millions of dollars annually. Therefore, the protection of streambanks against erosion has gained national attention. The importance of such attention will increase as demands on the nation's streams grow. As urban areas and public facilities increase in number along the nation's waterways, the adverse effects of streambank erosion will become even more objectionable.

Effective streambank protection measures have been costly to install and to maintain. In a report to the Secretary of the Army by the Chief of Engineers (1969) it was estimated that the cost of preventive treatment for 148,000 miles of seriously eroding streambanks would be approximately $420 million annually. This indicates that many of the areas suffering damages cannot be economically justified for treatment using methods previously employed. For this reason, research programs are needed to develop cheaper and more effective methods of treatment. In cooperation with the U.S. Army Corps of Engineers and the Soil Conservation Service, the USDA Sedimentation Laboratory initiated studies during the latter part of 1978 on stream channels in Panola County, Mississippi, to determine the feasibility of using vegetation to help stabilize and control streambank erosion.

STATEMENT OF PROBLEM AND NEED FOR STUDY

A literature survey by personnel of the U.S. Army Engineer Waterways Experiment Station (Keown, et al., 1977) indicates that only limited research has been done on the use of vegetation to stabilize streambanks except on very small channels and agricultural waterways. Vegetation is commonly used to stabilize small agricultural storm runoff conveyance systems such as terrace channels, grassed waterways, and small dam emergency spillways (Ree and Palmer, 1949; Ree, 1957, 1976 and 1977). Here, grassy species do the complete job of stabilizing both bank and bed. On small ephemeral channels, native volunteer vegetation, primarily woody species, often stabilize banks but without proper management may flourish to the extent of encroachment upon the stream and create drainage problems by clogging the waterway. As a result, expensive cleanout operations often become necessary. On larger ephemeral channels, conditions may exist where growth of native vegetation will help to stabilize streambanks, but rarely does the vegetation contribute to channel bed stabilization. Prior research by the USDA Sedimentation Laboratory has helped to establish the quantity of erosion that may occur in unstable channels (Bowie, 1980). The data from these studies show that up to 55 percent of the total sediment yield measured from a complex watershed in North Mississippi was contributed by channel erosion. The computed yield from channel bank erosion was as much as 1,860 tons per mile per year.

Observations and conclusions on the establishment, use, and effectiveness of vegetation for stabilizing streambanks have been discussed in detail by Edminster et al. (1949) and by Porter and Silberberger (1960) for streams in the northeast and by Logan et al. (1979) for the upper reach of the Missouri River in North Dakota. Despite the knowledge gained in these studies, much additional information is needed about the potential use of vegetation as a bank stabilization method. Studies are needed on streams that have different geologic and soils formation and hydrologic characteristics. Because of the many factors that influence streambank erosion, more research is needed in the following areas: (a) a determination of the maximum velocities that various vegetative materials can withstand along the bank boundary as related to soil type and degree of

bank slope; (b) studies to determine, in terms of durability and initial cost, the vegetative and structural designs that are most economically effective; and (c) establishment and maintenance requirements, including methods of improving and extending the life cycle of the plant cover. The effects of vegetation as a stabilizing media generally are not adequately recognized in design criteria for open channels. There is urgent need for practical criteria that can be effectively used by conservationists and engineers for incorporating vegetative erosion control measures as an integral part of channel planning and design.

3 HYPOTHESIS AND RESEARCH OBJECTIVES

Studies by the USDA Sedimentation Laboratory on the use of vegetation to stabilize streambanks and control erosion were established on the following hypothesis: (a) vegetation is the most important and the most readily available material for streambank stabilization; (b) both woody plants and herbaceous vegetation properly established and managed will provide the cheapest source of protection and play an important role in stabilizing channel banks; (c) vegetation will greatly reduce the water velocities and tractive forces on the bank to a value below that required to cause erosion; (d) vegetation properly established and managed will provide esthetic benefits, enhance the environment for fish and other wildlife habitat, and will not excessively reduce the carrying capacity of streams; (e) the effectiveness of expensive structural material required for stabilizing severely eroding channel banks can be greatly enhanced by using a proper combination of vegetation with the structural material. Implied in these hypotheses is the necessity for learning the limitations of vegetation as a material for stabilizing channel banks. Vegetation should not be construed to be a cure-all for all bank erosion problems, e.g., it must not be used on areas where the conditions are so severe that it cannot be established or maintained.

Several definable questions remain to be answered for research on vegetative control of streambank erosion for channels varying in bottom width from a few feet to over 100 feet. The most prominent of these are: (a) How small must a channel be in terms of size, discharge, and mean flow velocity to be controlled with grassy species; (b) what soil and hydraulic conditions are necessary for vegetative control of bank erosion with grassy and/or woody species; (c) what are the soil and hydraulic conditions where vegetation must be protected by structural materials until growth is sufficient for stability.

With the above questions as a guide, general research objectives were developed as follows:

1. Evaluate the effectiveness of various species of grassy and woody plants for stabilizing streambanks and floodways.
2. Determine the proper combination of structural materials and vegetation for the most effective and economical control of streambank erosion.

3. Determine the type and scope of maintenance required to sustain, improve, and extend the life cycle of the vegetative material.

The specific objectives are:

1. Determine the erosion control effectiveness of woody species behind existing retards in several channel locations.
2. Determine the erosion control effectiveness of woody and grassy species on straight channel reaches.
3. Determine the effectiveness of various types and varieties of structural materials and vegetation in several different combinations on shaped and prepared banks in selected channel bends and straight reaches.
4. Determine the effect of soils, hydrological, and plant development conditions on bank erosion.
5. Determine the best system for maintaining effective erosion control with vegetation alone and in combination with structural material.

Data necessary to evaluate the studies include (a) periodic cross-section surveys of the channel study reaches; (b) continuous record of stream flow stages; (c) storm discharge rates at various stages; (d) point and mean velocity at various stages; (e) records of precipitation and air temperature; (f) soil moisture levels during the growing season; (g) soil fertility and pH levels of bank material; (h) stability of structural materials; (i) growth and stability of vegetative materials; (j) documented inspections following major storm events; (k) photographic documentation of all phases of on-site field research from initiation to completion of studies.

4 RESEARCH APPROACH AND PROCEDURES

4.1 LITERATURE REVIEW

Although published reports are rather limited, a review of the literature reveals that different approaches to the use of vegetation for stabilizing eroding streambanks have been tried. Of the methods or techniques referred to (Edminster, 1949; Edminster, et al., 1949; Silberberger, 1959; Porter and Silberberger, 1960; Stanton and McCarlie, 1962; Logan, et al., 1979), the ones most frequently used were (a) vegetation in conjunction with structural devices without bank shaping; (b) vegetation in conjunction with structural material with bank shaping; and (c) vegetation with bank shaping and no structural material. The only logical alternative to the above methods is vegetation without bank shaping and no structural measures. This technique was implemented in previous studies by the author of this paper and will be discussed in more detail under the section headed Preliminary Results and Discussion.

One of the early advocates for the use of vegetation to stabilize streambanks was Dr. James Anderson of Scotland in 1776 (Tabor, 1960). His method is considered to have merit in modern watershed work. It consisted of sloping unstable stream banks, above and below the waterline, of sodding or seeding the slope with grass and planting aquatic vegetation at and somewhat below the waterline. Where the stream was rapid or unstable at the toe of the bank, he recommended that loose stones be used in conjunction with the vegetation to protect the toe and lower bank.

4.2 SELECTION OF STUDY AREA

The only restrictions directed to the USDA Sedimentation Laboratory in selecting locations for the streambank vegetative studies were that the general intent of the Corps of Engineers Cooperative Program on Streambank Erosion Control Evaluation and Demonstration be complied with. This required selecting channels with bank erosion problems that were considered representative of other channels throughout the southeast and other sections of the country. Also, channel inflow would not be restricted, controlled, or influenced in any way by large reservoirs.

Three channels, Johnson, Goodwin, and Peters Creeks located in Panola County near Batesville, Mississippi (Fig. 1), were selected as meeting these criteria. Johnson and Goodwin Creeks are tributaries to Peters Creek which in turn forms an integral part of the upper Yazoo River Basin. The

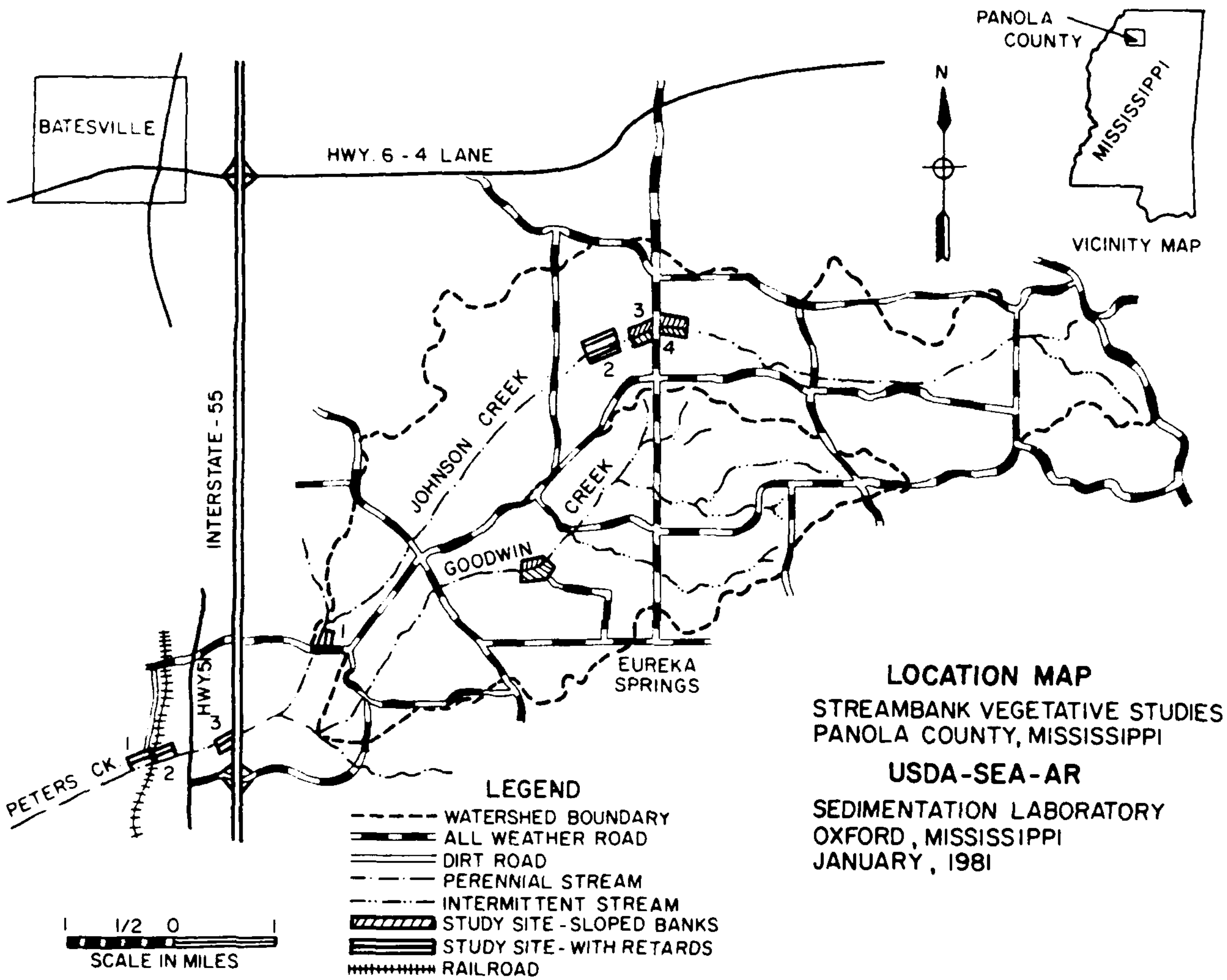

Figure 1 Location map of streambank vegetative study area.

three study reaches on Peters Creek and Johnson Creek Nos. 1 and 2, as shown in Fig. 1, were selected primarily for research on the use of woody species of plants in conjunction with preconstructed structural devices without bank shaping.

4.3 DESCRIPTION OF CHANNEL STUDY REACHES

A complete and detailed description of the physical properties and geology of the channels in the study area are given in Appendix E. Generally the bank is composed of alluvial soils, and in most reaches, the channel bottom consist of a mixture of sand and gravel. Along those reaches where bed instability is most pronounced, channel banks are vertical and quite deep (Fig. 2). Bank instability is due primarily to the height of the bank, erosion of the lower bank toe, and internal bank pressure created by lateral movement of groundwater. Figure 3 is a classic example of the channel bank failure prevalent throughout the study area.

Two locations were selected on Johnson Creek for studies using vegetation in conjunction with bank shaping and structural materials and also bank shaping without structural materials. As shown in Figure 1, the two study reaches, Numbers 3 and 4, are separated by a highway bridge. The downstream section, Number 3, is a 1,600 ft. straight reach of channel with several combinations of treatments along 2,900 linear ft. of bank. The upstream section, Number 4, is a 600 ft. bend-way with several combinations of treatment along the concave (outside) and convex (inside) bends. The banks along both study reaches average 15 ft. in height with channel bottom widths ranging from 20 to 35 ft. During 1980, construction of a grade control structure approximately 100 ft. downstream from the Number 3 study reach reduced the bed gradient from 18.6 ft. per mile to 8.1 ft. per mile. The bed gradient for the Number 4 bend-way study reach was unaffected by the structure and remained at 17.4 ft. per mile. The catchment area above the two reaches consists of a drainage network of approximately 6.2 sq. miles.

The two additional study reaches on Johnson Creek are treated with vegetation in conjunction with structural devices without bank shaping. The Number 2 study reach (Fig. 1) is located along 1,200 ft. of channel bend-ways. The woody specie water elm (Planera aquatica) is planted between riprap retards and the sharp concave bends. The Number 1 study

Figure 2 Typical Channel Cross Section of Johnson Creek.

Figure 3 Johnson Creek Bank Failure Due to Undermining.

reach is located along 132 ft. of a sharp concave bend with the woody specie, river birch (Petula nigra), planted between the bank and a wooden fence retard.

The Goodwin Creek location (Fig. 1) was also selected for using vegetation in conjunction with bank shaping and structural materials and bank shaping without structural materials. The study reach is located in a 500 ft. bend-way with natural S-shaped banks. Several combinations of treatment were included along the concave and convex bends. The banks average 10.6 ft. in height with channel bottom widths ranging from 30 to 40 ft. The bed gradient is approximately 26 ft. per mile. The catchment area above the study reach is approximately 5.4 sq. miles.

The Peters Creek study reaches were treated with woody vegetation in conjunction with structural devices without bank shaping. The three study sites are located along relatively straight reaches of channel (Fig. 1). The vertical banks average approximately 15 ft. in height with channel bottom widths ranging from 75 to 125 ft. The Number 3 site is located in a Kellner jack field along the left bank for a distance of 500 ft. River birch is planted between rows of concrete jacks that form a combination of diversion and retard lines. The Number 2 site, located along the right bank for a distance of 500 ft. is planted to streamco willow (Salix purpurea 'Streamco'). The plantings are made between the bank and concrete jack diversion line. The Number 1 site is located in a Kellner jack field along the right bank for a distance of 1,000 ft. Native black willows (Salix nigra) are planted between rows of concrete jacks that form a combination of diversion and retard lines.

4.4 DESIGN CRITERION

Based on observations and prior research, it becomes quite obvious that methods for stabilizing eroding streambanks must vary with different conditions. The type of protection needed for a specific case is largely determined by the characteristics of the channel. Factors which must be considered in selecting control measures include: the height of bank; stability of bank material; the stability of channel bottom; channel width; curvature of stream; bed gradient; availability of protective materials; utilization of property adjacent to the channel; and allotted resources and cost of implementation.

The potential of a stream to erode its banks not only varies from one section to another, but is persistently high in some locations (Parsons, 1960; Edminster, et al., 1949). The type of protection needed for banks having straight alignment differs from the treatment required for banks at curves and in reaches where the higher velocities come close to or strike the bank. In straight channels the higher velocities are usually near the center of the channel and close to the water surface. Therefore, more flexibility is permitted in the choice of protective materials. In channel bends the highest velocity is close to the concave bend and near the center of water depth. Because of the excessive erosive force exerted on the concave bend, a more substantial type of protection is needed. As a general rule the opposite shore line tends to build up by deposition, therefore, there is much less need for protection along the convex bend.

Consideration must be given to the stability of the streambed. If channel conditions are such that the potential for bed degradation exist, extra protection will be required along the toe of the bank and to some depth below the normal stream bed. In order to keep the cost to a minimum, only that quantity of structural material considered adequate for protection should be used. Under all circumstances, those structural materials suitable for the job with the least cost of purchase and installation should be utilized.

Where channel formation and hydrologic characteristics permit, and due to the high cost of structural materials, vegetative materials should be used to the fullest extent possible. The purpose of the vegetation is to provide a dense permanent cover that will prevent the streamflow from eroding the channel banks while maintaining the channel capacity. Maximum use should be made of acceptable native vegetation. The qualities that suitable vegetative materials should have are: all species must withstand the degree of inundation contemplated; provide year-round protection; establish well under severe soil conditions; be long lived; develop a root system sufficiently extensive to resist the drag of the streamflow on the tops; multi-stem and branch characteristics with many stems emerging from the boundary surface; stem and branch characteristics of toughness and resilience; and require minimum maintenance.

Since most unstable channel banks have been eroded and undercut to a very steep unplantable slope, bank shaping is mandatory for establishment

of the grassy species and also for many of the shrub type woody species. Bank slopes should be constructed at 2:1 or flatter (i.e., 2-feet horizontal to 1-foot vertical). On banks of less than 2:1 slope, the vegetation does not grow well because all plant roots have a tendency to grow straight down. The steeper the slope, the less rooting volume the plants have.

Stockpiling and respreading the topsoil to a depth of 8-10 inches on the sloped bank may be required where channel slope material, after excavation, is not adequate for establishing herbaceous vegetation. Fertilizer and lime needs should be determined by soil test, and when required, applied prior to seeding and worked into the seed-bed to a depth of 6-8 inches. Most herbaceous vegetation grow best in soil with pH levels of 6.5 to 7.0. An adequate mulch cover, properly anchored, should be applied immediately after seeding to conserve moisture, increase infiltration, and prevent rainfall erosion. Spoil and all areas along the top of finished banks should be graded with sufficient slope to prohibit the flow of accumulated surface water over the face of the bank. The entire vegetative area should be protected from livestock and other traffic by permanent fencing.

4.5 CONSTRUCTION OF STUDY REACHES

4.5.1 Johnson Creek Study Reach No. 3

In the design of the Goodwin Creek and the Johnson Creek study reaches Nos. 3 and 4, the above established criteria were utilized to the fullest extent possible. A schematic of the site plan for the Johnson Creek study reach No. 3 is shown in Fig. 4. Nine treatment sites ranging from 200 to 470 ft. in length are included in the study. The combination of treatments for each site is listed in Table 1. The top two feet of soil along both sides of the channel was stockpiled and later used on the prepared seedbeds.

The excavated-bench method, with lower bank and toe protection by structural revetment, was used for bank sloping treatment sites no. 1, 2, 3, 4, and 6. The purpose of the excavated bench is to provide a better environment for establishing woody vegetation. The toe of the lower bank along sites no. 1, 2, and 4 was provided with extra protection by heavy rock riprap placed in a trench excavated to a minimum of 2.5 ft. below the existing channel bottom (Fig. 5). The course of the channel bottom was not

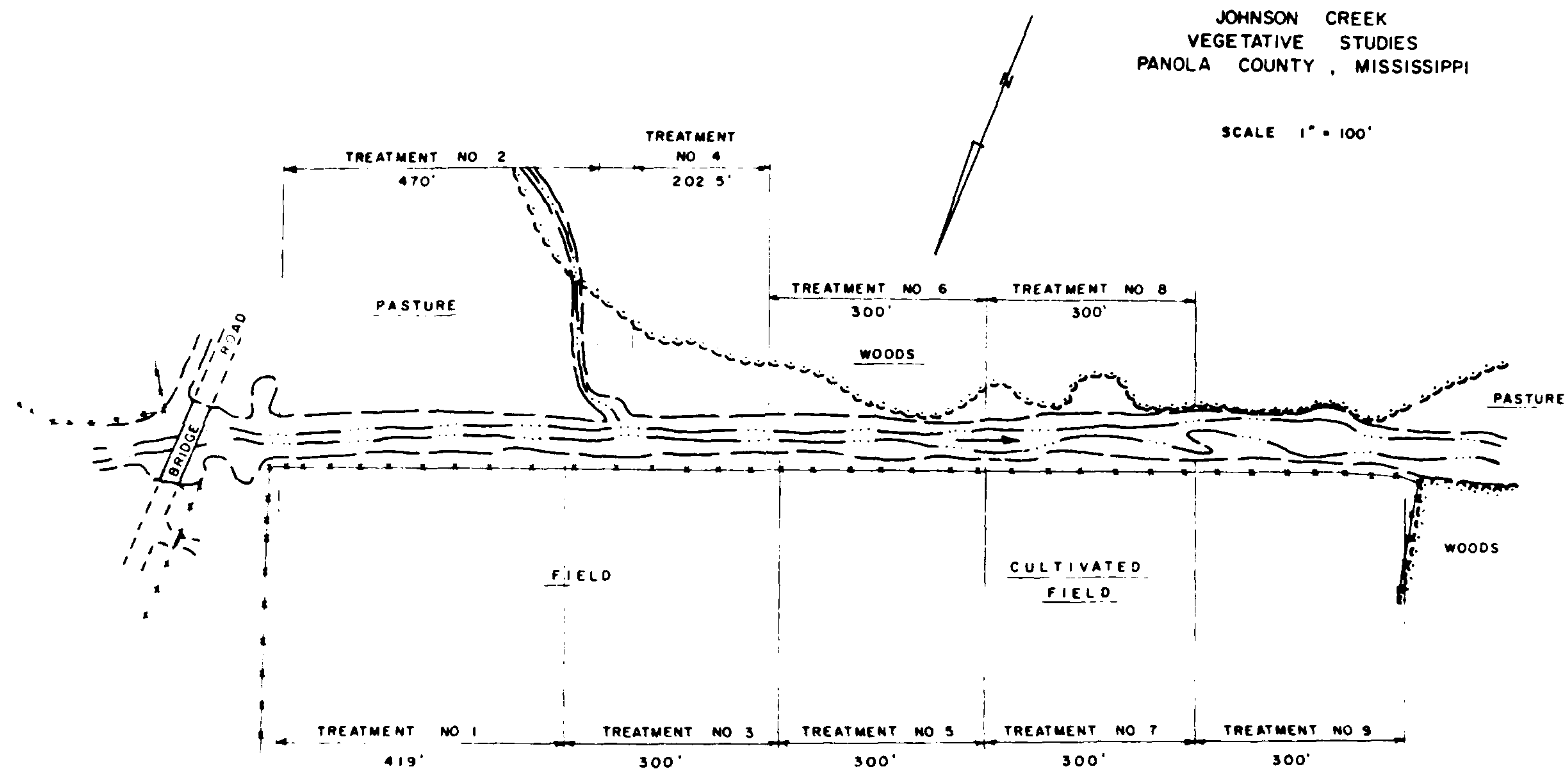

Figure 4 Site Plan of Johnson Creek Study Reach No. 3

TABLE 1. DESCRIPTION OF JOHNSON CREEK TREATMENT SITES FOR STUDY REACH NO. 3

Treatment	Structural Materials		Vegetative Materials			
Number	Toe	Lower Bank	Bench	Upper bank	Berm	Mulch Materials
Site 1	Riprap	Riprap	Indigo bush	Bahiagrass	Bermuda	Emulsified asphalt & straw
Site 2	Riprap	Cellular block[1/]	Bristly locust	Bristly locust &	Bermuda	Paper netting
Site 3	Cellular block	Cellular block & bermuda	Indigo bush	Crown vetch	Bermuda	Paper netting
Site 4	Riprap	Cap blocks[1/]	Indigo bush	½ Alamo switch-grass, ½ Reed Canary grass	Sericea	Paper netting
Site 5	Cap blocks	Cap blocks	-	Reed Canary grass	Bermuda	Paper netting
Site 6	Cellular block	Cellular block	River birch	Sericea	Sericea	Paper netting
Site 7	Riprap	Streamco willow	-	Bermuda	Bermuda	Excelsior blanket
Site 8	Sand clay gravel	Sand clay gravel & bermuda	-	Sand clay gravel & bermuda	Sericea & bermuda	Paper netting
Site 9	-	Bermuda	-	Alamo switchgrass	Bermuda	Excelsior blanket

1/ Concrete material

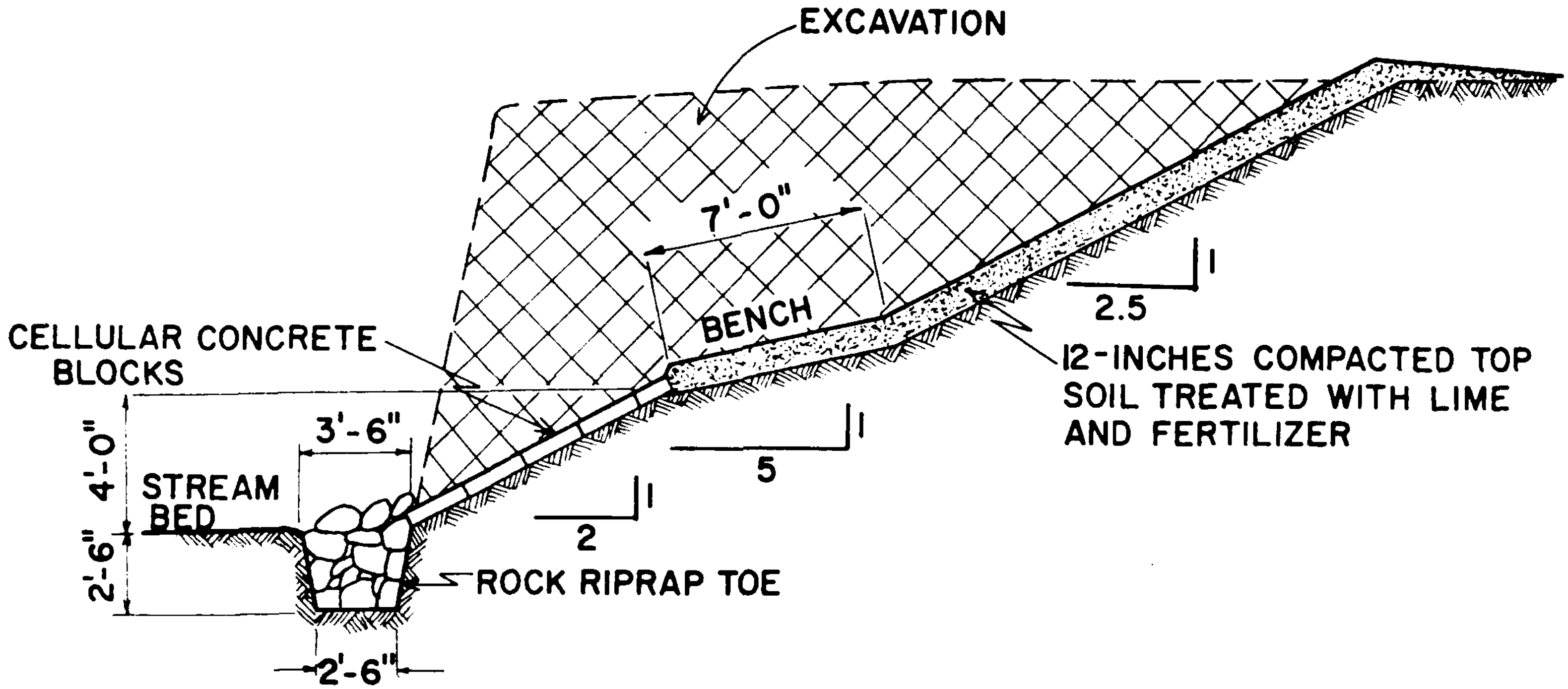

Figure 5 Johnson Creek Study Reach No. 3 - Excavated Bench Section with Lower Bank and Entrenched Toe Protected with Structural Materials

altered during construction. The lower bank was protected with either rock riprap, cellular concrete blocks, or concrete cap blocks. Plastic filter cloth of woven polypropylene fabric was installed between the revetment and subgrade. The design height of 4.0 ft. of structural revetment on the lower bank was approximated by the maximum depth of flow for 90-95 percent of the annual storm events. The lower bank is constructed to a 2:1 slope, the 7.0 ft. wide bench to a 5:1 slope, and the upper bank to a 2.5:1 slope. The bench is planted to woody species and the upper bank to herbaceous species. Sites no. 7, 8, and 9 were constructed to a 2.5:1 slope without structural materials (Fig. 6). The entire bank is planted to herbaceous vegetation. All of the bank seedbeds were treated with 800 lbs. of 13-13-13 commercial fertilizer and 4,000 lbs. of lime per acre, incorporated into the top 8 inches of soil, seeded, and covered with erosion control mulch material.

The contract for the Johnson Creek study reach no. 3 was awarded to the Neil Bain Contracting Company of Holly Springs, Mississippi on October 19, 1978 for the sum of $138,784.00. A contract change was awarded June 8, 1980 for $16,000.00 for additional work. The total contract cost for the project was $154,784.00. Work was performed under USDA, SEA, AR Contract No. 50-7B30-9-82. On site construction began November 4, 1978 and was completed June 20, 1979.

A downstream view of the study reach just prior to construction is shown in Fig. 7. A view from the same location after completion of construction is shown in Fig. 8.

4.5.2 Johnson Creek Study Reach No. 4

A schematic of the site plan for the Johnson Creek study reach No. 4 is shown in Fig. 9. Six treatment sites ranging from 50 to 125 ft. in length were included on the shaped bank of the concave bend. The entire length of the convex bend is considered as one treatment site. The finished bank along the concave bend consists of fill material excavated from the opposite (convex) bank. The bank of the convex bend was shaped to a 2:1 slope without structural materials, except for a hard point constructed at the upstream end (Fig. 9). The bank of the concave bend was shaped to a 2:1, 2.5:1, and 3:1 slope in conjunction with structural materials as shown in Fig. 9. The bed of the stream was relocated toward

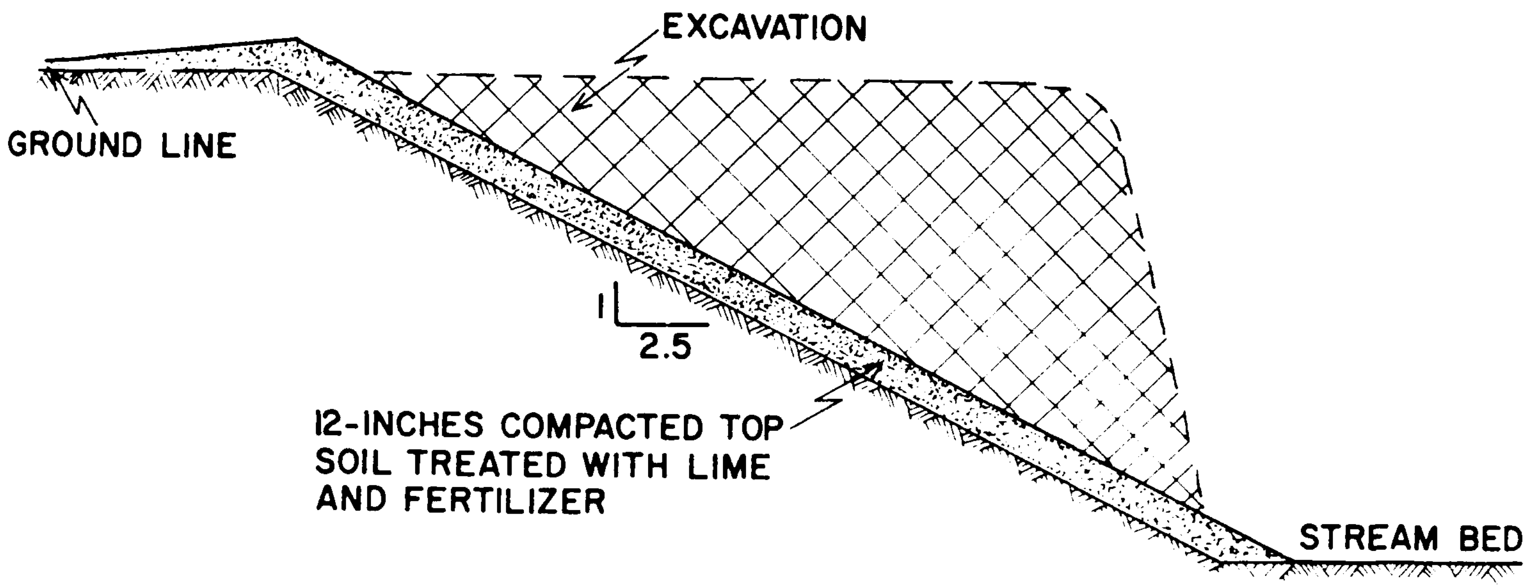

Figure 6 Johnson Creek Study Reach No. 3 - Typical Sloped Bank Without Structural Materials

Figure 7 Downstream View of Johnson Creek Study Reach No. 3 Prior to Construction

Figure 8 Downstream View of Johnson Creek Study Reach No. 3 After Construction Completed

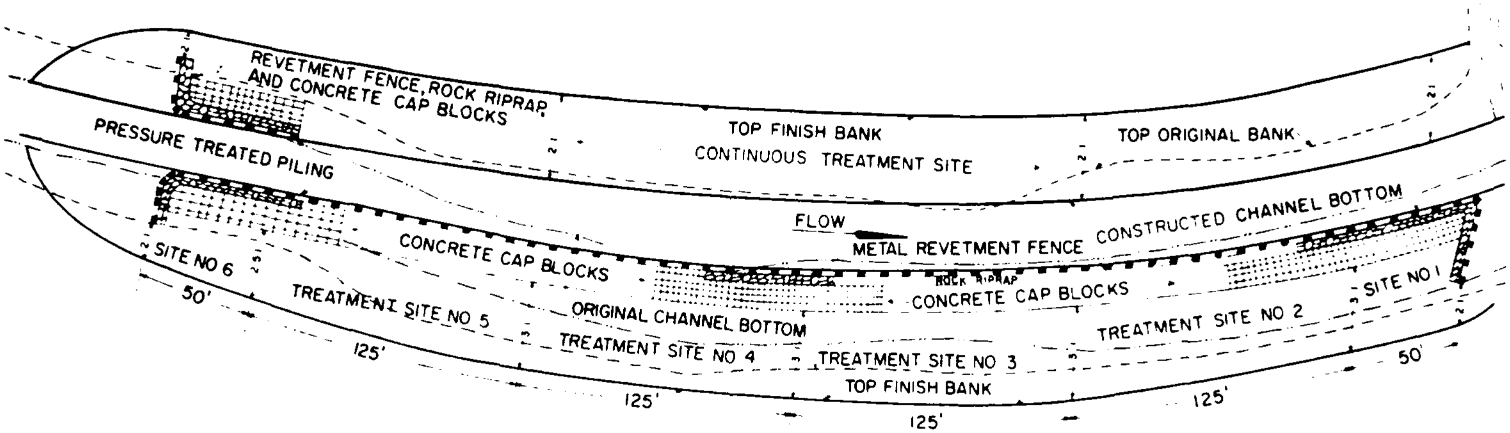

Figure 9 Site Plan of Johnson Creek Study Reach No. 4

the inside curve of the channel in order to: decrease and smooth the curvature of the concave bend; obtain a flatter bank slope for the concave bend without infringing on adjacent farm land; establish a more uniform bottom width; and provide needed fill material.

A trench 5 ft. wide by 3 ft. deep was excavated at the toe line of the finished bank along the concave bend. Creosote pressure treated piling, with a minimum tip diameter of 8 inches and 16 ft. in length, were driven on 8 ft. centers in the excavated toe trench and adjacent to the channel bottom. The piling was driven to a depth of 2 ft. above the finished grade of the stream bed. A chain link fence, 60 inches in height and of 9 gauge galvanized steel fabric, was attached to the side of the piling adjacent to the bank being protected. The toe trench was backfilled with riprap to the top of the fence (Fig. 10). The lower bank is protected with 4" x 8" x 16" concrete cap blocks placed between and anchored by 11 gauge galvanized wire netting, which in effect forms an articulated matting. The design height of 6.0 ft. of structural revetment on the lower bank, as shown in Fig. 10, was approximated by the maximum depth of flow for 90-95 percent of the annual storm events and the additional erosive force expected to be exerted on the concave bend. The upper bank will be planted to herbaceous vegetation.

All of the bank area along the convex bend was planted to annual ryegrass for temporary cover and to unhulled bermuda grass seed for permanent cover. The toe of the bank along the convex bend will be planted to woody vegetation. All of the bank seedbeds were treated with 800 lbs. of 13-13-13 commercial fertilizer and limed at the rate of 4,000 lbs. per acre, incorporated into the top 8 inches of soil, and covered with emulsified asphalt treated mulch. As shown in Fig. 10, the top of the finished bank was sloped away from the channel to prevent drainage of surface water over the face of the slope.

The Johnson Creek study reach No. 4 was part of a contract awarded to the R. C. Stacks Construction Company of Ripley, Mississippi on September 26, 1980. This part of the contract was for the sum of $86,888.00. Work was performed under USDA, SEA, AR Contract No. 50-7B30-0-320. On site construction began October 23, 1980 and was completed January 2, 1981.

An upstream view of the study reach prior to construction is shown in Fig. 11. A view from the same location after completion of construction is shown in Fig. 12.

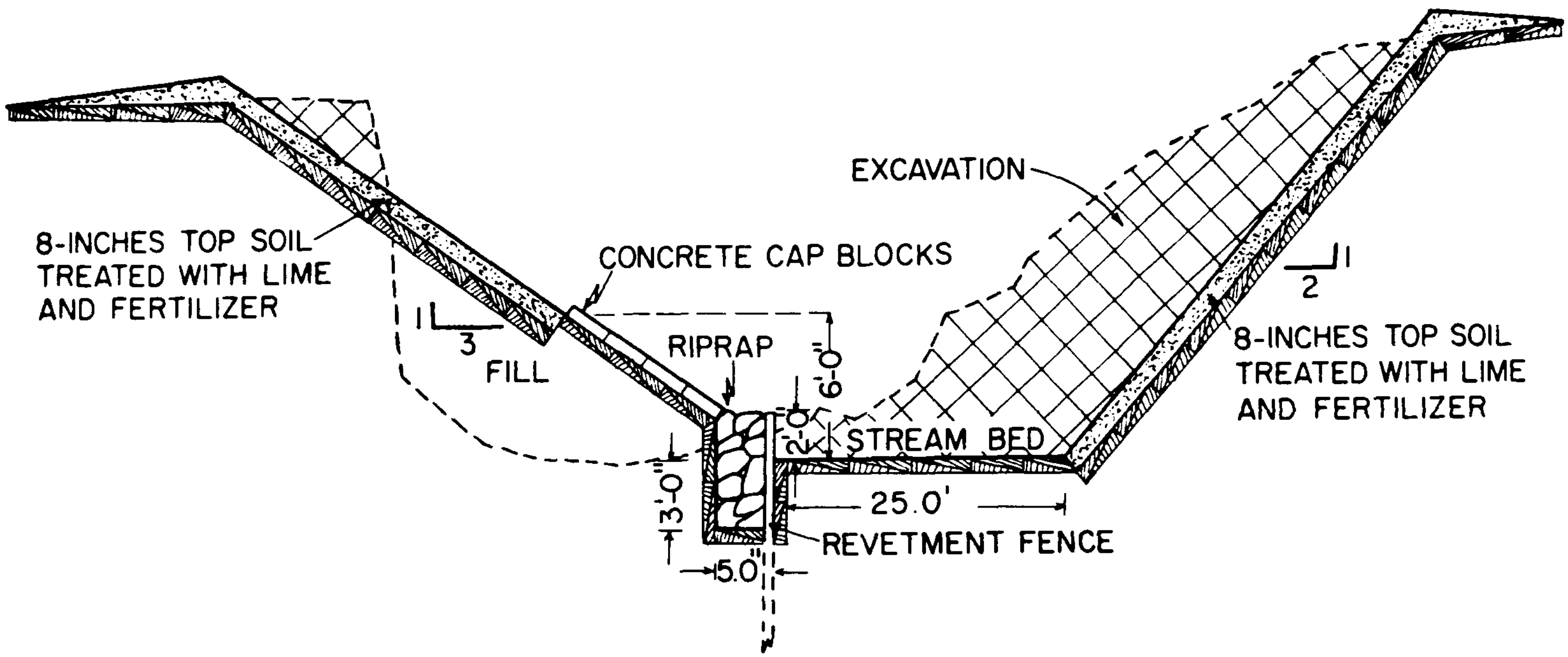

Figure 10 Typical Finished Cross Section of Johnson Creek Study Reach No. 4

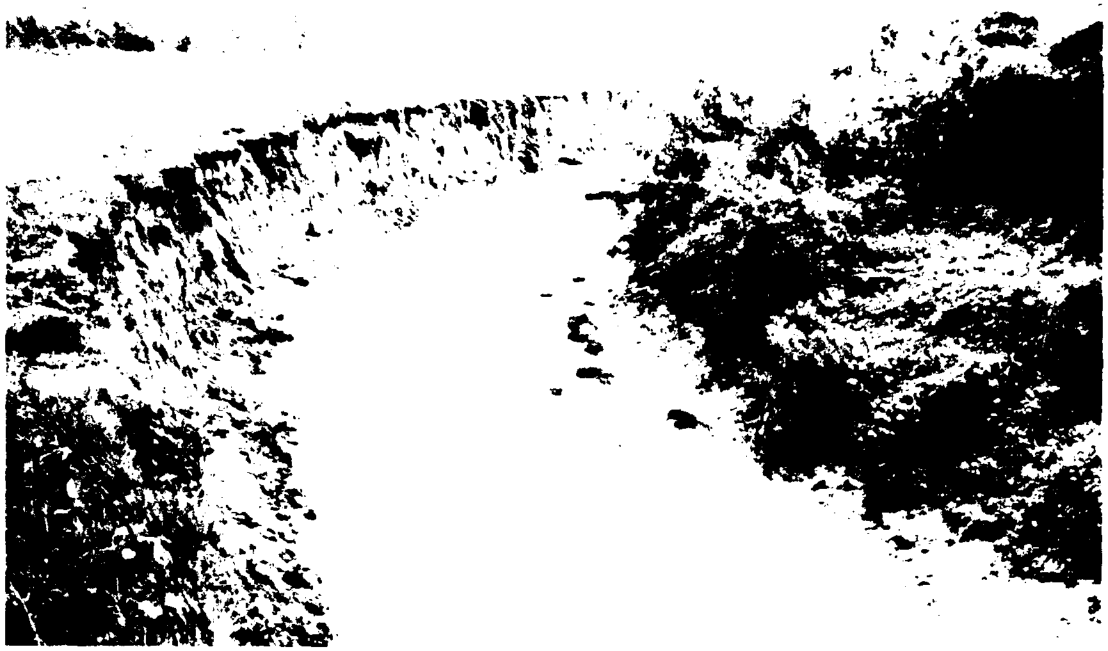

Figure 11 Upstream View of Johnson Creek Study Reach No. 4 Prior to Construction

Figure 12 Upstream View of Johnson Creek Study Reach No. 4 After Construction

4.5.3 Goodwin Creek Study Reach

A schematic of the site plan for the Goodwin Creek study reach is shown in Fig. 13. Seven treatment sites with lengths ranging from 100 to 120 ft. will be included on the shaped bank of the concave bends. Three treatment sites, each 100 ft. in length, will be included along the convex bend. The finished bank along most of the concave bends will consist of fill material excavated from the opposite (convex) bank. The bank of the concave bends will be shaped to a 2:1, 3:1, and 4:1 slope in conjunction with structural materials as shown in Fig. 13. The bank of the convex bend will be shaped to a 3:1, 4:1, and 5:1 slope without structural materials.

The bed of the stream will be relocated toward the inside curve of the channel for the same purpose as stated for the Johnson Creek study reach No. 4. Also, the same specifications and method of construction for the concave bend will be used, except as follows: The lower bank will be protected with 4.5" x 16" x 24" cellular concrete blocks weighing 90 lbs. each. The design height of 5.0 ft. of structural revetment on the lower bank, as shown in Fig. 14, was approximated by the maximum depth of flow for 90-95 percent of the annual storm events and the additional erosive force expected to be exerted on the concave bend. The upper bank will be planted to herbaceous vegetation.

The bank area along the convex bend will be planted to both grasses and shrubs. The toe area along the convex bend will be planted to tree type vegetation. All of the bank seedbeds will be treated with 800 lbs. of 13-13-13 commercial fertilizer, limed at the rate of 4,000 lbs. per acre and incorporated into the top 8 inches of soil; seeded and planted; and covered with emulsified asphalt treated mulch. As shown in Fig. 14, the top of the finished banks will be sloped away from the channel to prevent drainage of surface water over the face of the slope.

The contract for the sum of $86,297.00 for the Goodwin Creek study reach was awarded to the R. C. Stacks Construction Company of Ripley, Mississippi on September 26, 1980. Work will be performed under USDA, SEA, AR Contract No. 50-7B30-0-320. On site construction has been delayed in order that the completion date will provide for a more optimum time for planting the vegetation. The scheduled completion date is April 21, 1981.

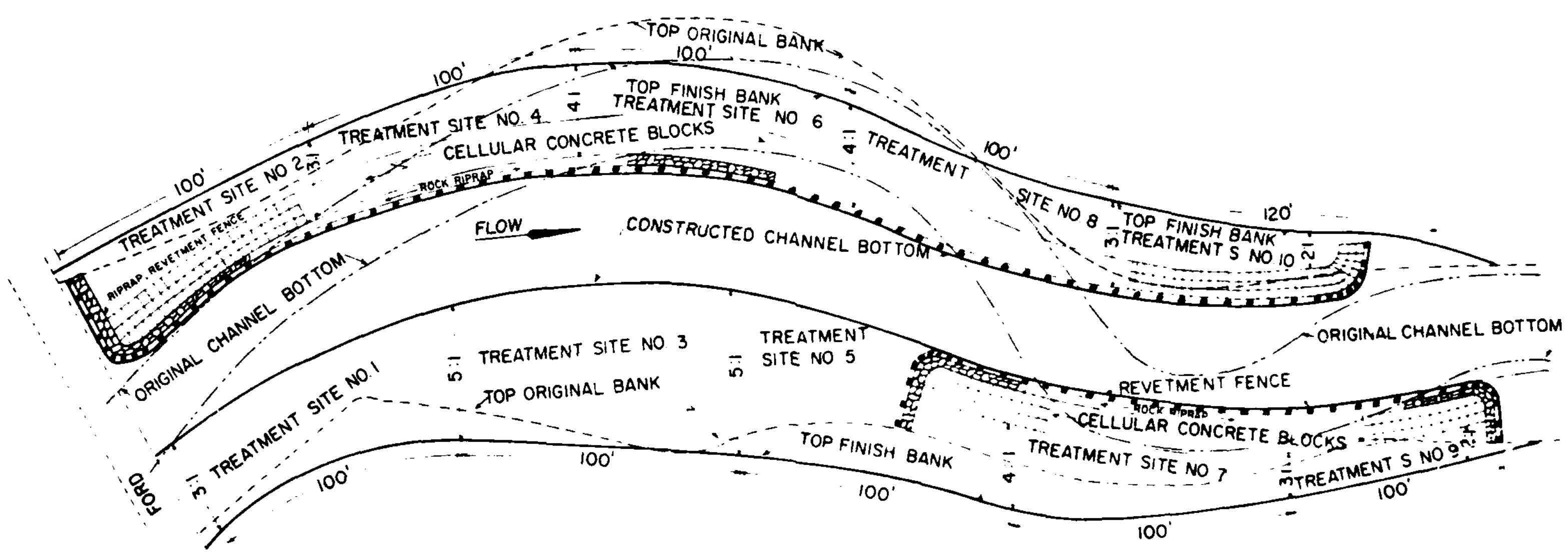

Figure 13 Site Plan of Goodwin Creek Study Reach

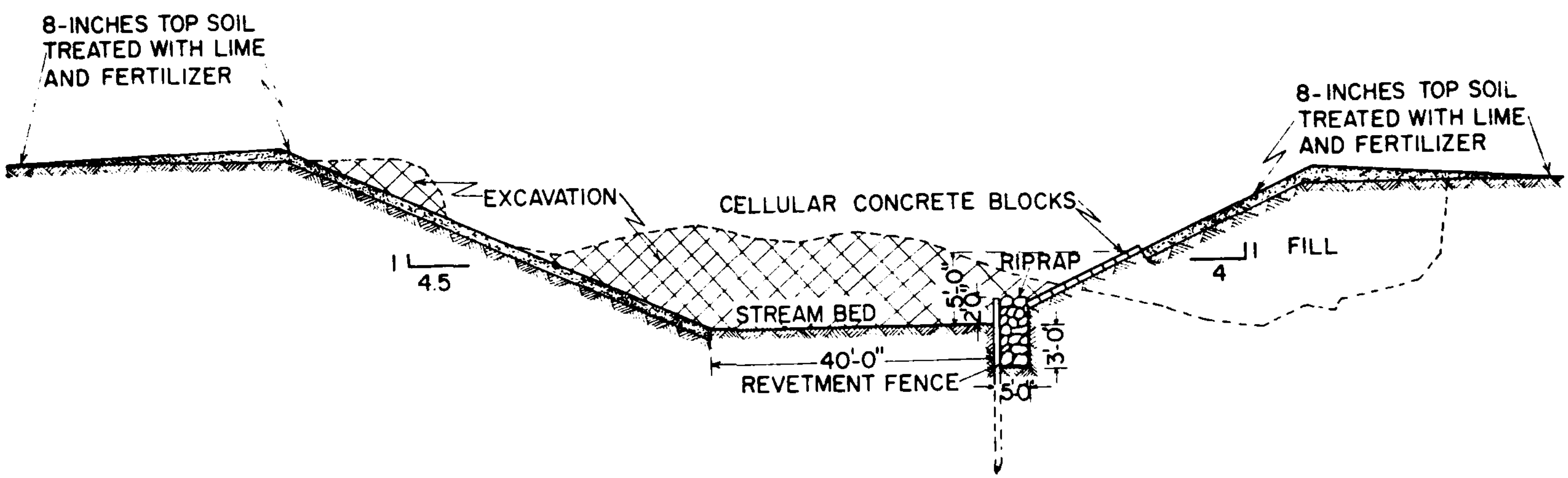

Figure 14 Typical Finished Cross Section of Goodwin Creek Study Reach

5 PRELIMINARY RESULTS AND DISCUSSION

Stages in the propagation of vegetation are generally recognized as planting and germination, growth, development, and maturity. The time required to reach maturity or stage of maximum production varies greatly, depending upon the species and growth environment. Under a good environment with a proper balance of soil moisture and plant nutrients, at least two growing seasons are required to establish a dense cover for many of the grasses. More than five years will be required to obtain appreciable growth for most woody species. Observations by Porter and Silberberger (1960), on vegetative work along the Buffalo Creek in northwestern New York State, have shown that the shrub types require four to seven years before effective cover is obtained. It becomes quite obvious, therefore, that a number of years are required to properly evaluate most plant material studies. With only two growing seasons for the Peters Creek and part of the Johnson Creek studies, any conclusions made at this time would be premature. There are some observations, however, that are considered worthy of mention.

The checking or elimination of scouring forces creating channel bed degradation is necessary before satisfactory results can be expected from the use of vegetation to stabilize or control bank erosion. In many cases, failure of bank protective works can be attributed to the failure of the bank toe from scour, which in turn creates undercutting and sloughing of the upper bank. The history of the Johnson Creek channel in recent years has been one of a series of progressive head cuts. Prior to selection of Johnson Creek vegetative study reaches nos. 3 and 4, plans and specifications were developed by the USDA Sedimentation Laboratory and the Corps of Engineers to construct a series of grade control structures to help stabilize the channel bottom. Unfortunately, the awarding of a contract for installing the planned structures was delayed until approximately two years after study reach no. 3 was initiated. During this period of time, cross section surveys of the study reach revealed that the channel bottom degraded 3.1 ft. In a few locations, the rock riprap and cellular concrete block revetment on the lower bank slid down the bank to the eroded toe line and exposed small areas of filter cloth. Most of the displaced material continued to protect the lower bank at the toe line and prevented any bank failure.

All of the no. 3 study reach was subjected to severe hydrologic and plant growth stresses during 1980. Large storm runoff events, occurring early in the year, produced velocities in excess of 12.0 ft. per second at the center of the stream and 2.5 to 3.0 ft. per second near the bank along both sides of the channel. However, no appreciable damage to the treatment sites was observed. During the growing season, 4.89 inches of precipitation was recorded. Normal rainfall during this period is approximately 15.0 inches. Although plant growth was retarded by the drouth the survival rate for the woody species was considered better than average for the prevailing conditions. The overall survival rate for the 1979 and 1980 plantings of the shrub type bristly locus (Robinia fertilis arnot) and indigo bush (Amorpha fruticosa) was 94 percent and 78 percent respectively. The 1980 planting of Streamco willow had a survival rate of only 33 percent. Crown vetch on 7,500 sq. ft. bank area had a survival rate of 83 percent. All of the grassy species responded well and formed a good dense ground cover. Only one treatment site, a formed bank armoured with 6-inches of compacted sand clay gravel and over-seeded with bermuda grass, failed to show good growth and ground cover. However, the survival rate of the bermuda was considered good. Due to the length of time anticipated for the shrub types to provide adequate cover for protection, grassy species have been interplanted with the shrubs. The most effective mulch materials one year after seeding were found to be excelsior erosion control blankets, and chopped grain straw anchored with emulsified asphalt. Paper matting was considered to be the least satisfactory.

Species of woody vegetation in conjunction with retards on Johnson and Peters Creek have shown varying degrees of response. A survey was made two years after planting to determine the survival rate for each study reach. The results of the survey, made during the latter part of 1980, are as follows: Johnson Creek study reach no. 2, Water elm planted between channel bank and riprap - 60 percent survival; Johnson Creek No. 1, river birch planted between channel bank and wooden fence - 60 percent survival; Peters Creek No. 1, native black willow planted between channel bank and concrete jacks - 75 percent survival; Peters Creek No. 2, Streamco willow planted between channel bank and concrete jacks - 32 percent survival; and Peters Creek No. 3, river birch between channel bank and concrete jacks -

55 percent survival. The Peters Creek study reach no. 1 with native black willow planted between the channel bank and rows of concrete jacks is shown in Fig. 15.

Vegetating without bank shaping and no structural measures is usually limited to woody species. Native species such as willows are the easiest to propagate. The degree of success is determined by the size of the channel, height and stability of bank material, maximum velocities and characteristics of flow along the channel banks, the amount and type of material deposited along the bank toe line, and whether or not planting is attempted along a concave bend. The greatest problems exist along concave bends and is the most difficult to vegetate without the support of retards.

Studies to determine the feasibility of vegetating channel banks without bank shaping and without the support of structural materials were initiated in 1976 and 1977 by the USDA Sedimentation Laboratory and the Soil Conservation Service. Plantings of various species of willows were made in 1976 along both banks of a 6,000 ft. dredged reach on Pigeon Roost Creek in Marshall County, Mississippi. One bendway was included in the upper reach of the study. The vertical banks average 12 ft. in height with channel bottom widths ranging from 120 to 130 ft. The channel bed, with a gradient of approximately 7 ft. per mile, is slowly degrading. The catchment area above the study reach is approximately 100 sq. miles. Survival evaluations were made in April 1980 with the following results: native black willow - 32 percent survival; halbert willow (Salix hastata MS-863) - 11 percent; gilg willow (Salix gilgianna MS-859) - 15 percent; and slender willow (Salix gracilis MS-878) - 23 percent survival.

Plantings of various woody species were made in 1977 along both banks of a 330 ft. straight reach on Oaklimeter Creek in Benton County, Mississippi. The vertical banks of this natural channel average 15 ft. in height with bed widths ranging from 15 to 25 ft. Survival evaluations of the plantings were made in April 1980 with the following results: gilg willow (MS-859) - 12 percent survival; slender willow (MS-878) - 54 percent; Carolina willow (Salix caroliniana MS-4375) - 21 percent; river birch - 54 percent; and hazel alder (Ainus rugosa MS-3516) - 37 percent survival.

Failure of plants to survive in both studies is attributed to high flow velocities (>3.0 ft./sec.) near the channel banks, bank sloughing due

Figure 15 Peters Creek Study Reach No. 1 - One Year Growth of Native Black Willow Planted in a Kellner Jack Field

to reduction of shearing resistance from saturation and erosion of the toe, bank slides due to freezing and thawing, and generally poor unproductive soils.

Preliminary results obtained at this early stage of the studies indicates that native species of both grassy and woody plants are preferable over imported varieties. Sprigging is preferred over seeding for crown vetch and the ivies. Good stands of most grasses have been obtained by seeding. Native black willow appears to be superior to the hybrid varieties of willow in both survival and growth. River birch, alders, and water elm show some potential when planted under the right environment. The shrub varieties, indigo bush and brisley locust, have responded well.

A discussion of stream bank stabilization work would be incomplete without including maintenance. No stabilization program, regardless of how well designed, will remain effective without some maintenance. Control measures, once installed, are not automatically permanent. Structures installed in conjunction with vegetative plantings will in time deteriorate or they may become ineffective due to changes in hydrologic or physical characteristics of the stream. The plant cover itself is subject to change from destructive physical action and through natural laws of plant succession. Too much plant growth can reduce channel capacity. On-site appraisal of channel conditions is necessary to detect possible weak points and to schedule necessary maintenance and repairs before potential problems reach the acute stage. A regular maintenance program will greatly prolong the useful life of stabilization measures, prevent loss of work previously done, and will safeguard the banks against possible erosion in the future.

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